MONITORING OF AERIAL INSECTICIDE SPRAYING AGAINST THE SPRUCE BUDWORM IN QUÉBEC, 1984:

CONCENTRATIONS OF CHEMICAL INSECTICIDES IN THE AIR INSIDE AND OUTSIDE (3KM) THE TREATED AREAS

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ABSTRACT

In its aerial insecticide spraying operations against the spruce budworm (Choristoneura fumiferana), the ministère de l'Énergie et des Ressources carried out in 1984 for the third consecutive year a sampling program aimed at determining the concentrations of chemical insecticides inside and outside (±3km) the treated areas. Three different sampling methods were tried inside and four outside to determine the effect of the technique on the results.

Inside the treated areas, widely varying concentrations of aminocarb were detected with each method used; results go from undetected (<24 ng-min/l) to a maximum of 2160 ng-min/l for 120 minutes after application. Outside the treated areas, the aminocarb concentrations are very low or undetectable (maximum 56.8 ng-min/l) for the same sampling time.

For fenitrothion only two sampling stations were monitored and the maximum values were respectively 1452 and 71.2 ng-min/l inside and outside the treated areas.

Inside the areas treated with aminocarb, a statistical comparison of methods was carried out. Tests showed that the fixed flow and direction pump and the Rotorods generally underestimated concentrations respectively by 43% and 67% compared to the results of the pump adjusted for ideal isokinetic sampling conditions.

In spite of the differences in means, we observed a highly significant correlation ($\alpha = 0.01$) between the adjustable pump and the Rotorods and a less significant correlation ($\alpha = 0.05$) between the adjustable pump and the fixed flow pump. Furthermore, highly significant correlations were observed between the concentrations in air samples collected by the adjustable pump or the Rotorods compared to those samples taken from aluminum foil on the ground.

Results indicated that for aminocarb detection both methods observing isokinetic conditions (adjustable pump and Rotorods) were consistent with one another and with the concentrations measured on the ground.

Outside the treated areas ($\pm$3km) it was very difficult to compare the four methods employed -- the pump adjusted for 3 l/min, another for 0.6 l/min, the U and H shaped Rotorods -- because of the large proportion of undetected concentrations.

In the light of our results and the advantages and disadvantages of each of the methods, we recommend the adjustable pump for air sampling inside the treated areas and the use of the 3 l/min pump for sampling outside these areas.

TABLE OF CONTENTS

ABSTRACT.....i

TABLE OF CONTENTS.....iii

LIST OF TABLES.....iv

LIST OF FIGURES.....iv

1. INTRODUCTION.....1

2. TERRITORY.....2

3. METHOD.....4

3.1 - Spraying 4
3.2 - Insecticide formulations.....4
3.3 - Air Sampling 6
3.3.1 Inside the treated areas.....6
3.3.2 Outside the treated areas.....9
3.4 - Analytical Method.....10
3.4.1 Insecticide in the air.....10
3.4.2 Insecticide deposits on the ground.....12
3.5 - Preliminary tests on Rotorod effectiveness.....13

4. RESULTS.....16

4.1 - Inside areas treated with aminocarb.....16
4.2 - Inside areas treated with fenitrothion.....22
4.3 - Outside areas treated with aminocarb.....22
4.4 - Outside areas treated with fenitrothion.....26

5. DISCUSSION.....28

5.1 - Inside the treated areas.....28
5.2 - Outside the treated areas.....31
5.3 - Recommendations.....32

APPENDIX I - Wind speed and direction observed every five minutes during air sampling inside the treated areas.....34

APPENDIX II- Properties of droplet spectra at each of the air sampling sites.....38

BIBLIOGRAPHY.....42

LIST OF TABLES

Table 1: Chemical insecticide formulations on spray blocks where air samples were taken in 1984.....5

Table 2: Rotorod effectiveness for aminocarb retention during laboratory tests.....14

Table 3: Aminocarb concentrations in the air and on the ground inside the treated areas.....17

Table 4: Statistical comparison of different sampling methods.....19

Table 5: Fenitrothion concentrations in the air and on the ground inside the treated areas.....23

Table 6: Aminocarb concentrations in the air and on the ground outside the treated areas.....24

Table 7: Fenitrothion concentrations in the air and on the ground outside the treated areas.....27

LIST OF FIGURES

Figure 1: Spruce budworm spraying program in Québec in 1984.....3

1. INTRODUCTION

In accordance with its program of controlling harmful insects in the forest environment and Order-in-Council 2615-83, the ministère de l'Énergie et des Ressources in the spring of 1984 carried out its fifteenth aerial insecticide spraying operation in order to reduce damage caused by the spruce budworm (Choristoneura fumiferana).

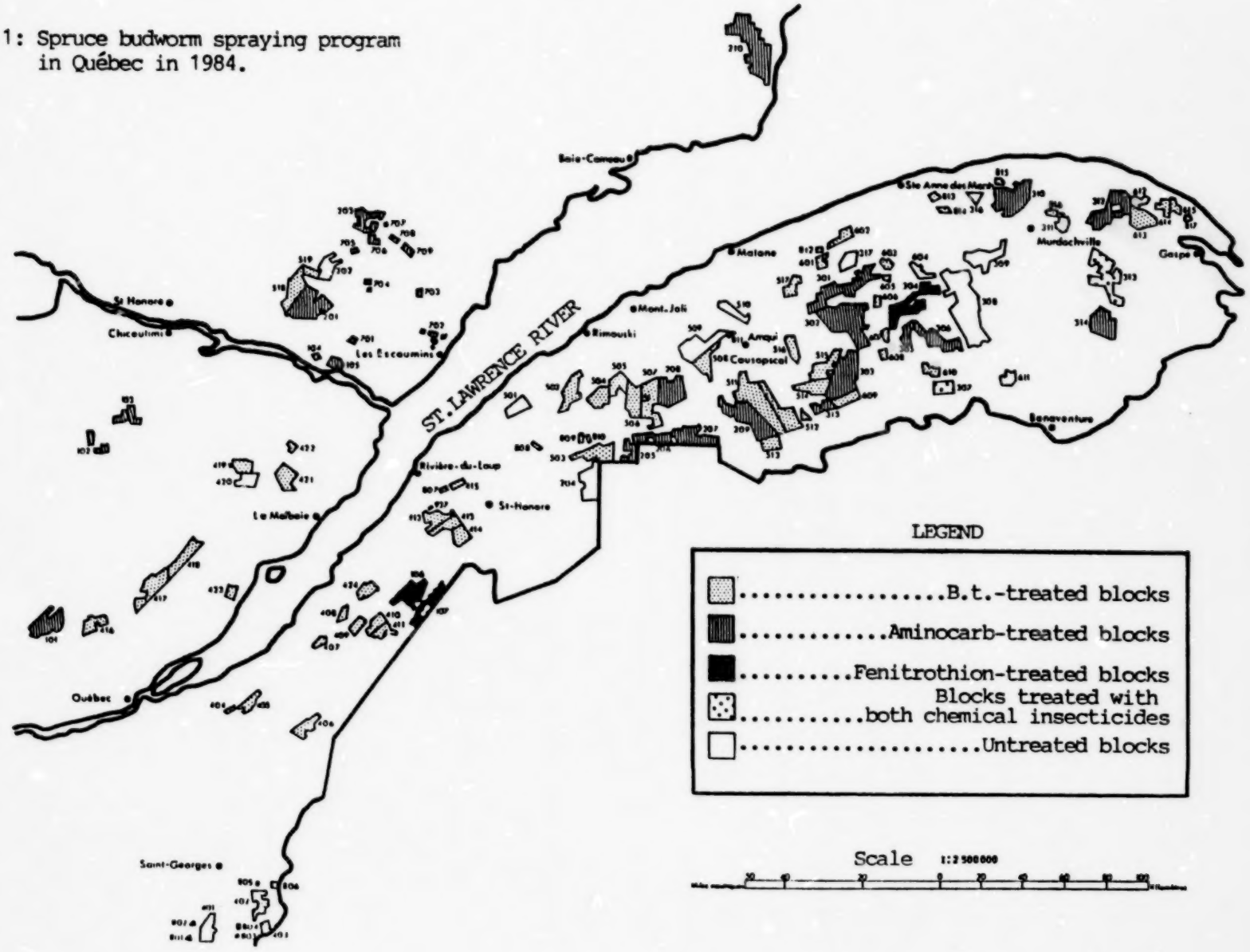
Within this context the department carried out for a third consecutive year a sampling program to determine insecticide concentrations in the air. As in previous years,one part of this program involved measuring chemical insecticide concentrations inside and outside (≈3km) the treated areas. However, contrary to previous programs, various sampling methods were used simultaneously in order to verify the effect of the method on the data.

This report deals with the results obtained for the 1984 monitoring program and presents a comparison between the various sampling techniques.

2. TERRITORY

The region sprayed in 1984 extends over all of southeastern Québec covering a surface of 673 046 hectares (Fig.1). Of this area 299 064 ha (44.4%) were treated with aminocarb, 33 594 ha (5.0%) with fenitrothion and 34 063 ha (5.1%) with both of these chemical insecticides. The remaining surface covering 306 325 ha (45.5%) was treated with biological insecticides.

Figure 1: Spruce budworm spraying program in Québec in 1984.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3. METHOD

3.1 - Spraying

The spraying program was carried out from May 18 to July 3 with Constellation L-749, DC-4G and DC-6 four-engine aircraft or AgCat and Turbo Trush single-engine aircraft. We should mention, however, that only those blocks sprayed by four-engine aircraft were covered by this study. The spraying system for these aircraft consisted of booms fitted with #8010 flat jet nozzles. The blocks sprayed by the four-engine aircraft received a second application after about five days, but some of them only received a single application either because of unfavourable weather conditions or due to a sizeable decrease in larvae populations after the first application.

3.2 - Insecticide Formulations

The chemical insecticides used in this study were aminocarb (Matacil^{MD}180D) and fenitrothion (Sumithion^{MD}) at rates of 52 and 210g of active ingredients per hectare respectively. Table 1 provides a detailed description of these insecticide formulations.

Table 1: Chemical insecticide formulations on spray blocks where air samples were taken in 1984.

Active matter (Commercial product)	Rate (g/ha)*	Formulation volume (1/ha)	Formulation V/V			
			Commercial Product (%)	Cyclosol 63 (%)	Diluent** (%)	Dye (%)
Fenitrothion (Sumithion 95%)	210	1.4	11.3	40	48.2	0.5
Aminocarb (Matacil 180D MD)	52	1.4	20.8	--	78.7	0.5

* active ingredient
** oil 585

3.3 - Air Sampling

3.3.1 - Inside the treated areas

Before describing the methods used, we should mention required sampling conditions. In an aerosol cloud, air sampling must be carried out under isokinetic (the air speed in the sampling tube equal to the speed of cloud movement) and isoaxial conditions (tube pointing directly into the wind). These conditions allow one to give a representative figure for product concentrations in the air (Fuchs, 1975; CNRC, 1982). Sample air flows that are too low or too high respectively produce an overestimation or underestimation of the real concentrations.

In order to evaluate the spread of data due to sampling techniques, three sampling methods were used simultaneously:

(1) The first method employed a Dupont^{MD}P-4000 pump with adjustable flow and direction installed on the roof of a van. Changes in flow and direction were made every five minutes in accordance with wind speed and direction changes monitored by a Met One^{MD}010B wind speed sensor and a Met One^{MD}022B bi-vane sensor. This method allows one to approach the ideal sampling conditions mentioned earlier. The reason for installing equipment on the roof of a van is to obtain slightly higher wind speeds for the weather instruments

than the barely detectable levels measured on the ground.

(2) The second method used the same model of pump, but with fixed flow and direction, similar to a method employed in 1983. The pump with a flow of 0.6 l/min was installed at a height of 1.5 m with its collector tube parallel to the road pointing generally into the wind.

For both of the above mentioned methods, the pumps are equipped with polyurethane collectors whose description and effectiveness have been discussed in a previous report (Major et al., 1984).

(3) The third method used an entirely different technique. The U-shaped Rotorods^{MD} employed inside the treated areas are fine metal rods which revolve at a speed of 2 400 RPM sweeping an air volume of 120 litres per minute. According to the manufacturer (Ted Brown Ass. 1984) the collection surface of the rods with a width of 1.59 mm achieve selective impaction of particles from 10 to 100μ. The equipment is installed at a height of 60 cm. It is worth noting that this technique is considered to be isokinetic under low wind conditions (Edmonds, 1972; Murray et al.,1970) and was tested in the laboratory with the results appearing in section 3.5.

Whatever the method, sampling began immediately after passage of the aircraft and continued over a period of two hours (4 x 30min for the Rotorods). This sampling procedure was chosen because of results obtained in 1983 which revealed very weak or undetectable concentrations (0.5 ng/l) after this period (Major et al., 1984). At the beginning of each sampling period three Kromekote^{MD} cards and three pieces of aluminum foil were put on the ground at the site. The former are used to obtain a picture of the droplet spectra while the latter give information on quantities of insecticide reaching the ground.

All sites were located in the middle of the treated area and between 200 and 400 m downwind of the flight path in order to obtain maximum concentrations of insecticides. They were selected in relatively open country near the edge of a road 8 to 20 m wide.

After sampling, the polyurethane collectors were wrapped individually in aluminum foil and kept cold (4^{o}C) in a container until their arrival at the laboratory. The samples were then frozen until the time of analysis. For Rotorods a new rod was installed at the end of each 30 minute period. Each branch of the contaminated rod was suspended inside a sample bottle and washed with 50 ml of ethyl acetate in a wash bottle. These samples were then conserved in the same manner as the polyurethane filters.

In all, 10 applications of aminocarb and 2 of fenitrothion were monitored for a total of 12 sites.

3.3.2 Outside the treated areas

Outside the treated areas considering the distances involved (≤3km) and the dilution of insecticide, the isokinetic sampling conditions were not critical. The four methods, however, were applied simultaneously to obtain comparable data.

The first two methods are very similar to method number 2 described in the preceding section using a Dupont P-4000 pump with fixed flow and direction. In one case the pump was adjusted to work at 0.6 l/min and in another at 3 l/min in order to test the effect of sample flow on results. In both cases the collectors were facing the treated areas and pointing in the direction of the wind.

The other two systems employed Rotorods. In one case the device was equipped with U-shaped rods described in the preceding section; the other device was equipped with H-shaped rods, 0.48 mm wide, considered to be efficient by the manufacturer for drops of from 0 to 10μ and sweeping an air volume of 52 l/min (Ted Brown Ass. 1984). We should mention however that the latter device was not used for the two sites treated with fenitrothion.

As inside the treated areas, the sampling procedure was carried out for a period of two hours (4 x 30 min for the Rotorods) beginning after the passage of the aircraft on the closest flight path. A two hour sampling period was chosen because the results obtained in 1983 showed very weak or inexistent concentrations after this period (Major et al., 1984). To detect ground deposits, three Kromekote cards and three sheets of aluminum foil were put down on the ground at each site. All sites were located at about 3 km from the treated areas and downwind in order to measure a maximum drift outside the target area. The exposure of these sites was similar to that of sites inside the treated areas.

After sampling, handling procedures were identical to those described in the previous section. Eleven applications of aminocarb and two of fenitrothion were monitored in this project aimed at measuring the drift of insecticides at a total of 13 sites.

3.4 - Analytical Method

3.4.1 Insecticide in the air

The extraction of fenitrothion and aminocarb were carried out according to a slightly modified version of the acephate extraction technique published by Wright et al. (1981).

The polyurethane is deposited in a 100 ml glass beaker and then immerged in 15 ml of ethyl acetate. The contents are left to soak for five minutes, then the liquid is poured into a 500 ml volumetric flask by pressing the polyurethane foam against the sides of the beaker. The extraction process (immersion, soaking and pouring off) is repeated five times successively with 15 ml of ethyl acetate. With a rotative evaporator, the solution is reduced to a vol of about 1 ml, to which is added about 10 ml of toluene, and then reduced again to a volume of 2 to 3 ml. The concentrate is then transferred to a 5 ml centrifuge tube and evaporated down to 0.3 ml under a gentle stream of nitrogen.

For the Rotorods, the samples arriving at the laboratory have already undergone extraction. They are then transferred into a 500 ml volumetric flask and concentrated in the same manner as that employed for the polyurethane foam.

The identification and quantification were carried out with two Hewlett Packard^{MD} gas chromatographs, models 5730A and 5890A, each equipped with two detectors specifically for nitrogen and phosphorus (NPD). Pyrex columns with lengths of 180 and 60 cm were used respectively for fenitrothion and aminocarb. These columns with an interior diameter of 2 mm are saturated with 4% OV-101 + 6% OV-210 on Gas Chrom Q (80-100 mesh) for identification and with 3% OV-17 on the same support for confirmation. The temperatures of the various compartments and the gas flow are as follows:

- Temperature:	Furnace	190	130
(^{o}C):	Injection	250	150
:	Detection	300	300
- Gas flow:	Helium	30	30
(ml/min):	Air	70	50
:	Hydrogen	3	3

3.4.2 Insecticide deposits on the ground

The three sheets of aluminum foil are washed, each in 50 ml of ethyl acetate with a wash bottle. The organic extract is reduced to about 1 ml by a rotative evaporator in a water bath at 38^{o}C. For gas chromatography determinations, we replace the ethyl acetate by toluene by adding about 10 ml of toluene to the ethyl acetate extract and reduce again to a volume of from 3 to 4 ml. The concentrate is transferred to a 5 ml centrifuge tube and evaporated down to 1 ml under a gentle stream of nitrogen. The determination is carried out in the same way as for the polyurethane foam.

The interpretation of the droplet spectra on the Kromekote cards was done by the Spraying Techniques Division with a Hitachi^{MD}VKC2000 video camera equipped with a Wild^{MD}M420 binocular microscope lens and connected to a Sony^{MD} Trinitron CVM 1900 color television.

The cards are lit with an Intralux^{MD}600 power source. The magnification obtained with this system is 106 times.

All the visible droplets on a 4 cm^2 surface chosen at random are counted and grouped according to their stain diameter. The stain diameter groups are then transformed into real diameter groups with the help of a regression calculation.

3.5 - Preliminary tests on Rotorod effectiveness

To determine the amount of aminocarb retention on the collector, we deposit a known quantity of the insecticide on the collection surfaces of each rod. The rods are left for several minutes before turning on the rotorods. The insecticide is then extracted and analysed to determine the retention rate.

Our research work involved on the one hand treating the rods before their use and on the other fortifying them with insecticide in a toluene solution prepared according to the 180D operational formulation. The results of this study are presented in table 2.

For a sampling time of 15 minutes, the aminocarb retention by the treated or untreated Rotorods before use was found to be low (40%) by fortification in solution (tests A to H). The treatment of rods with liquid phase OV 101, 210 and 17, which are often used for insecticide determinations in our laboratory

Table 2: Rotorod effectiveness for aminocarb retention during laboratory tests.

"Rotorod" treatment before use	Sampling time (minutes)	Fortification level (μg)	Number of tests	% of average retention
A- None	15	1.0	2	36
B- Application of 2.5% OV-101	15	1.0	2	38
C- Application of 5% OV-101	15	1.0	2	6
D- 5 applications of 5% OV-101	15	1.0	2	16
E- 5 applications of 5% OV-17	15	1.0	2	16
F- 5 applications of 5% OV-210	15	1.0	2	26
G- Coating with OV-101	15	1.0	1	6
H- Coating with OV-210	15	1.0	1	32
I- Coating with paraffin	15	21.4	2	54
J- Coating with silicone	15	21.4	2	42
K- None	15	21.4	6	83
L- None	120	21.4	4	43
M- None	15	1 to 7	12	95
N- None	30	13 to 17	4	77
O- None	60	11 to 15	4	57

NOTE: - Test A to H: fortification by 10μl of a 100 ng/μl aminocarb solution.
Test I to L: fortification by 1μl of a Matacil 180D formulation.
Test M, N and O: fortification by several drops (±500 microns) of a Matacil 180D formulation.

because of their great stability, were employed here in fixing the insecticide to minimize its volatilization.

The rod fortification in formulation 180D with pre-treatment (tests I and J) gave higher retention results than those obtained for the above-mentioned tests and even more with untreated collectors (83% for test K). However, for a sampling period of 120 minutes the results were only 43% (test L).

Test K gave such promising results that we decided to take a closer look at collector effectiveness by fortifying the rods with 500 micron droplets of an operational formulation and using sampling periods of 15 to 60 minutes (tests M, N and O). The highest retention rate (95%) was obtained for a 15 minute period. Retention rates then declined slowly as the sampling time increased (tests N and O). In view of acceptable retention effectiveness and the handling problems encountered in field work, we chose a 30 minute period (4 consecutive sampling times) for on-site air sampling.

4. RESULTS

Tables 3 to 7 present the results of this study. Two units are used: nanogram-minutes per liter of air and nanograms per liter of air. In the text, however,only time-integrated concentrations[1] expressed in ng-min/l are used because this unit is more significant. In fact, the concentration expressed in ng/l is an average value of the concentration present in the air during the sampling period, whereas the ng-min/l unit is the sum of the insecticide concentrations, which may have varied during the sampling period. We should mention that for the Rotorods the results given are the sum of the four concentrations obtained.

4.1 - Inside the areas treated with aminocarb

Table 3 presents the results of each site and each sampling method.

With the adjustable pump, the data goes from undetected (<24 ng-min/l) at site 1A-302 to a maximum of 2 160 ng-min/l at site 1A-207. For the fixed flow and direction pump, the minimum and maximum are found at the same two sites but the spread of data is much less: concentrations vary from 26.3 to 1 162.8 ng-min/l.

(1) The integrated concentration is the product of the detected concentration (ng/l) multiplied by the sampling time (minutes).

Table 3: Aminocarb concentrations in the air and on the ground inside the treated areas.

Date and site number	Afdp [1] ng-min/l (ng/l)	Ffdp [2] ng-min/l (ng/l)	"Rotorods U" ng-min/l (ng/l)	Aluminum (ng/cm^2)
84-05-28 a.m. 1A-302	<24 (<0.2)*	26.3 (0.219)	--	2.2
84-05-28 p.m. 2A-302	193.2 (1.61)	89.6 (0.747)	--	16.4
84-06-14 a.m. 1A-206	400.8 (3.34)	178.8 (1.49)	175.2 (1.46)	171.9
84-06-16 a.m. 1A-207	2 160 (18.0)	1 162.8 (9.69)	494.4 (4.12)	981.9
84-06-16 p.m. 1A-209	488.4 (4.07)	40.3 (0.336)	258.0 (2.15)	396.7
84-06-23 p.m. 2A-209	249.6 (2.08)	77.6 (0.647)	120.0 (1.00)	79.0
84-06-24 a.m. 3A-209	140.4 (1.17)	124.8 (1.04)	86.4 (0.72)	60.9
84-06-30 p.m. 4A-209	637.2 (5.31)	748.8 (6.24)	222.0 (1.8)	140.9
84-07-02 a.m. 5A-209	98.0 (0.817)	44.6 (0.372)	15.6 (0.13)	0.5
84-07-03 p.m. 1A-313	36.1 (0.301)	40.0 (0.333)	15.6 (0.13)	5.9

(1) adjustable flow and direction pump

(2) fixed flow (0.6 l/min) and direction pump

* undetected

Sampling with Rotorods was carried out at 8 of the 10 sites in the study. For these sites the results go from 15.6 to 494.4 ng-min/l. It is interesting to observe that with no results at site 1A-302 the minimum and maximum with this technique correspond respectively to the second lowest and to the highest values obtained with the pumps. The averages obtained with each method are indicated in table 4.

For the insecticide deposits on the ground at each of the sites, the sheets of aluminum foil showed concentrations of active ingredients varying from 0.5 ng/cm^2 to 981.9 ng/cm^2 with an average of 185.6 ng/cm^2. The Kromekote cards together with the aluminum foil allowed us to determine for all of the sites DMN* values varying from 31 to 65μ ($\bar{x}$=43) and maximum diameters of around 350 μ (real diameters). The droplet spectra for each of the sites is presented in detail in appendix 2.

Because of the large number of samples of aminocarb, a comparative analysis was performed on data from the various air sampling methods and the ground deposits (table 4). In the case of the air sampling procedures which have compatible units of measure, statistical analysis allows one to determine whether the difference between two series of paired observations are significant. The use of non-parametric statistics is favoured for two

* The DMN or the diameter of the median number is the diameter obtained when cumulative sum of the number of drops reaches 50% of the real number of drops.

Table 4: Statistical comparison of different sampling methods

	Afdp* (ng-min/l)	Ffdp** (ng-min/l)	Afdp Rotorods (ng-min/l)		Ffdp Rotorods (ng-min/l)		Afdp Aluminum$_2$ (ng-min/l)	(ng/cm^2)	Ffdp Aluminum$_2$ (ng-min/l)	(ng/cm^2)	Rotorods Aluminum$_2$ (ng-min/l)	(ng/cm^2)
Number of comparable observations	10	10	8	8	8	8	10	10	10	10	8	8
Mean	441.6	253.4	526.3	173.4	302.2	173.4	441.6	185.6	253.4	185.6	173.4	229.7
Standard deviation of the mean ($\sigma/\sqrt{n}$)	201.4	121.9	244.5	55.5	148.9	55.5	201.4	96.4	121.9	96.4	55.5	116.4
Kendall τ[1]	0.64		<u>0.91</u>		0.55		<u>0.78</u>		0.51		<u>0.91</u>	
Wilcoxon T	9		0		11		--		--		--	
Statistical decision[2]	H_o rejected		H_o rejected		H_o accepted		Inapplicable		Inapplicable		Inapplicable	

* Ajustable flow and direction pump
** Fixed flow and direction pump
(1) The underligned values indicate a highly significant relationship ($\tau \neq 0$) between methods ($\alpha < 0.01$).
(2) When $T_{obs.}$ is lower than the critical value ($T_{tab.}$), the equivalence hypothesis of the two methods$_{(Ho)}$ should be rejected ($\alpha < 0.05$).

reasons: the existence of data incompatible to the normal distribution and the limited number of observations. In this case the Wilcoxon T is the most appropriate test. Furthermore, in order to measure the strength of the relationship between the two methods, Kendall's coefficient of rank correlation was calculated.

In the case of the comparison between the insecticide in the air and on the ground, the units of measure are incompatible and therefore the comparison tests have no meaning and are inapplicable. The Kendall coefficient of rank correlation was however used here to evaluate the strength of the relationship between the two variables.

The comparison between the two pumps indicates a significant difference in the results. If one considers the ajustable pump as the method which best respects the isokinetic sampling conditions, one observes that the fixed pump underestimates on average the concentrations by 43%. The Kendall τ shows a significant correlation between the two methods. The critical value calculated here is on the borderline of significance for a probability level of 99% (α= 0.01).

There is also a significant difference between the mean concentrations obtained with the adjustable flow and direction pumps and those supplied by the Rotorods. The Rotorods gave results that were on average three times lower than those of the pumps. In spite of the great difference between the

means for the samples, the Kendall coefficient of rank correlation shows that the results obtained by the two methods are perfectly consistent.

For the comparison between the fixed flow pumps and the Rotorods, table 3 shows that the results of one method are sometimes higher and sometimes lower than those obtained with the other method. Consequently, we observed no significant correlation ($\tau \simeq 0$) between these methods at a confidence limit of 95% ($\alpha > 0.05$). Furthermore, because of the limited number of observations, we cannot say that they are significantly different. As a matter of fact, the Wilcoxon test considers them as statistically equivalent at a limit of $\alpha = 0.05$ and the observed discrepancies could depend on accidental variations in sampling procedures.

As explained earlier, the correlation between the concentrations in the air and on the ground was also determined. The calculated values of Kendall's τ indicate a highly significant relationship ($\alpha < 0.01$) between the ground deposit concentrations and those in the air detected by the adjustable flow and direction device and those values detected by the Rotorods. In the case of the fixed flow and direction pumps there was no significant correlation with the ground deposits.

4.2 - Inside areas treated with fenitrothion

For the sites 1A-106 and 2A-106 the results are respectively undetected (<24 ng-min/l) and 784.8 ng-min/l with the adjustable pump, undetected and 1 452 ng-min/l with the fixed pump, and 9.6 and 1 315.2 ng-min/l with the Rotorods (table 5).

The insecticide concentrations found on the ground with the aluminum foil are respectively 0.4 and 683.2 ng/cm^2 at these two sites. At the only site where the droplets could be measured, the DMN is 45μ and all the droplets are of a diameter inferior to 200μ. The details of the droplet spectra are shown in appendix 2. No statistical test could of course be applied to the two sites treated with fenitrothion.

4.3 - Outside areas treated with aminocarb

With pre-adjusted pumps at 0.6 l/min, the sampling gave results varying from undetected (<24 ng-min/l in 8 of 11 samples) to 50.6 ng-min/l. A higher sampling flow reduced the detection limit in the case of samples taken at 3 l/min (<6 ng-min/l). Consequently, the number of samples where the insecticide was not detected went from 8 to 6 and the maximum value of 56.8 ng-min/l was observed at a different site than for the preceding method (table 6).

Table 5: Fenitrothion concentrations in the air and on the ground inside the treated areas.

Date and number of the site	Afdp[1] ng-min/l (ng/l)	Ffdp[2] ng-min/l (ng/l)	Rotorods U ng-min/l (ng/l)	Aluminum (ng/cm^2)
84-06-10 p.m. 1A-106	<24* (<0.2)	<24* (<0.2)	9.6 (0.08)	0.4
84-06-12 p.m. 2A-106	784.8 (6.54)	1 452 (12.1)	1 315.2 (10.96)	683.2

(1) adjustable flow and direction pump

(2) fixed flow (0.6 l/min) and direction pump

* undetected

Table 6: Aminocarb concentrations in the air and on the ground outside the treated areas.

Date and site number	Pump 0.6 l/min ng-min/l (ng/l)	Pump 3 l/min ng-min/l (ng/l)	Rotorods U ng-min/l (ng/l)	Rotorods H ng-min/l (ng/l)	Aluminum (ng/cm^2)
84-05-28 a.m. 1A-302	<24* (<0.2)	<6* (<0.05)	--	--	1.1
84-05-28 p.m. 2A-302	<24* (<0.2)	<6* (<0.05)	--	--	1.0
84-06-14 a.m. 1A-206	36.4 (0.303)	56.8 (0. 473)	55.2 (0.46)	--	6.1
84-06-16 a.m. 1A-207	<24* (<0.2)	<6* (<0.05)	<1.2* (<0.01)	<1.2* (<0.01)	<0.08*
84-06-16 p.m. 1A-209	25.0 (0.208)	47.0 (0.392)	32.4 (0.27)	49.2 (0.41)	14.6
84-06-23 p.m. 2A-209	50.6 (0.422)	39.4 (0.328)	23.4 (0.26)	44.4 (0.37)	11.8
84-06-24 a.m. 3A-209	<24* (<0.2)	<6* (<0.05)	<1.2* (<0.01)	<1.2* (<0.01)	<0.08*

Table 6: (continued)

Date and site number	Pump 0.6 l/min ng-min/l (ng/l)	Pump 3 l/min ng-min/l (ng/l)	Rotorods U ng-min/l (ng/l)	Rotorods H ng-min/l (ng/l)	Aluminum (ng/cm^2)
84-06-30 p.m. 4A-209	<24* (< 0.2)	7.8 (0.065)	2.4 (0.02)	3.6 (0.03)	0.1
84-07-02 a.m. 5A-209	<24* (<0.2)	<6* (<0.05)	<1.2* (<0.01)	<1.2* (<0.01)	<0.08*
84-07-02 p.m. 1A-310	<24* (< 0.2)	<6* (<0.05)	<1.2* (<0.01)	<1.2* (<0.01)	<0.08*
84-07-03 p.m. 1A-313	<24* (<0.2)	13.8 (0.115)	13.2 (0.11)	21.6 (0.18)	2.9

* Undetected

** Sampling time: 1h. 30 min.

For the results obtained with the Rotorod technique, the U- and H-shaped rods were used respectively at 9 and 8 of the 11 sites in the study. With this technique, the detection limit was again reduced (1.2 ng-min/l) because of the very large volume of air swept by the rods. The U-shaped rods gave results which went from undetected (4 of 9 sites) to 55.2 ng-min/l while the concentrations with the H-shaped rods varied from undetected (4 of 8 sites) to a maximum of 49.2 ng-min/l.

The aluminum foil put on the ground at each of the sites showed measurable deposits at 7 of the 11 sites (>0.08 ng/cm^2) varying from 0.1 to 14.6 ng/cm^2. The deposits collected on the Kromekote cards were insufficient for a DMN evaluation, but showed that the majority of droplets had diameters less than 60μ (appendix 2).

4.4 - Outside the areas treated with fenitrothion

Of the two sampled sites, only one showed higher concentrations than the detection limit of each method. The results at this site were 71.2 and 34.8 ng-min/l respectively for the pump adjusted to 0.6 l/min and for the U-shaped Rotorods (table 7). At the site 2A-106 where the droplets could be measured the maximum diameter was about 80μ (appendix 2).

Table 7: Fenitrothion concentrations in the air and on the ground outside the treated areas.

Date and number of the site	Pump 0.6 l/min ng-min/l (ng/l)	Pump 3 l/min ng-min/l (ng/l)	Rotorods U ng-min/l (ng/l)	Aluminum (ng/cm^2)
84-06-10 p.m. 1A-106	<24* (<0.2)	<6* (<0.05)	<1.2* (<0.01)	<0.08*
84-06-12 p.m. 2A-106	71.2 (0.593)	--	34.8 (0.29)	21.3

* Undetected

5. DISCUSSION

5.1 - Inside the treated areas

Independent of the sampling methods, there is a great deal of variability in insecticide concentrations found inside the treated areas. This is evident in the spread of data for each method and the variability of the measured deposits on the sheets of aluminum foil. This inconsistency can be explained by meteorological conditions (temperature, humidity, wind speed and direction), local topography, differences in surrounding forest cover and the precise location of the site with respect to the flight path. Because of these factors, the sampled sites do not necessarily correspond to sites of maximum insecticide deposits in spite of our efforts.

A strong correlation between the sampling techniques that approximate isokinetic conditions is observed even though the Rotorods give lower concentrations than the adjustable pump. This constant underestimation of the Rotorods may be due to phenomena such as product evaporation, rod saturation or the splitting of droplets, which have a diameter larger than the limit of effectiveness for this technique. Furthermore, the results of this method seem to vary according to the size of the droplets (Kristmanson and Picot, 1983).

Comparing the two pumps, the difference between the mean values indicates the tendency of the pump with imprecise direction and fixed flow with regard to wind speed to underestimate concentrations. Appendix 1 shows the wind speed and direction changes for each site for periods of five minutes. The slightly lower correlation obtained for these two methods indicates a variable effectiveness for the fixed pump. Indeed, table 3 shows that certain sites give comparable or higher results with the "ffdp". Now it is possible that for these sites a large part of the insecticide fell during a time when wind speed and direction corresponded well with the fixed flow and direction values of the pump. In the case of the higher values they may be due to a rate of flow too low compared with wind speed during the spraying operation. This phenomenon may offer a possible explanation for the high values obtained with the fixed flow pump for fenitrothion at site 2A-106.

The excellent relationship between the aluminum foil deposits and the concentrations determined by the adjustable pump or the Rotorods shows the coincidence between concentrations detected on the ground and in the air by methods respecting isokinetic conditions. In the case of the fixed flow and direction pump, the variable effectiveness of the method as mentioned earlier probably produces the lack of correlation with the ground concentrations.

It is important to remember that all the statistical tests are based on a small number of samples and it would be premature to try to establish a regression model with the aim of predicting results from one method to another.

The results of this study are quite similar to those obtained in 1983 (Major et al., 1984). For comparable sampling methods (ffdp), the average aminocarb concentration of 253.4 ng-min/l (10 sites) is close to last year's result (230.5 ng-min/l for 23 sites). The maximum concentration of 1 162.8 ng-min/l is however greater than the 1983 value of 901.5 ng-min/l. In spite of the fact that the results are similar, it is important to mention that only the fixed flow and direction pump was used in 1983 and this method tends to underestimate by 43% concentrations in the air with respect to the adjustable pump. The new maximum detected by the adjustable pump (2 160 ng-min/l) is 2.4 times greater than the 1983 maximum. The average and maximum concentrations on the ground in 1984, respectively 185.6 and 981.9 ng/cm^2, are however lower than comparable 1983 concentrations of 244.5 and 1 535.8 ng/cm^2. The droplet spectra for both years are very similar with regard to DMN values which were 43μ in 1984 compared to 40μ in 1983.

5.2 - Outside the treated sites

The aminocarb concentrations at approximately 3 km from the treated areas are weak and show less spread than inside the treated areas (<24 to 56.8 ng-min/l).

Because of the large number of sites where insecticide concentrations were undetectable, no statistical test was applied. Table 6 shows that differences in detection limits make comparisons very risky. So it is impossible to tell the difference between the two pumps. The Rotorods seem to work better inside the treated areas and in particular the H-shaped rods which gave higher concentrations than the U-shaped ones. Given the small size of droplets suject to drift (Major et al., 1984) and the much lower insecticide concentrations outside the treated areas, the possibilities of rod saturation or big droplet splitting are greatly reduced. The systematically higher concentrations obtained with the H-shaped rods are possibily due to their effectiveness in detecting the smaller droplets (1-10μ).

Independent of the sampling methods, the maximum concentration of 56.8 ng-min/l determined during this study is lower than the 1983 maximum of 121.7 ng-min/l at a similar distance (Major et al., 1984). The maximum concentration of 14.6 ng/cm^2 on the ground is also lower than the 1983 value (22.45 ng/cm^2).

5.3 - Recommendations

In addition to the conclusions and recommendations of this study, we would like to discuss the advantages and disadvantages of each experimental method.

Inside the treated areas the aminocarb results showed the importance of isokinetic conditions during sampling. Among the methods adapted to these conditions, the Rotorods are cheaper and sweep a higher volume of air but tend to underestimate concentrations when used for periods of 30 min. Furthermore, their use requires tiresome handling procedures and the presence of volatile solvents in vehicles for their on-site extraction. The adjustable pump, even though it requires sophisticated meteorological equipment, is easy to use and adapts to ideal sampling conditions. The conditions are however not quite perfect because flow and direction corrections are made after each five minute period and not simultaneously with changes of wind speed and direction. This method seems to be the most

suitable for this kind of study and will be used in 1985 for the detection of biological insecticide (B.t.) inside the treated areas. The fixed flow and direction pump is not a good choice because its effectiveness depends on wind speed and direction.

Outside the treated areas, the Rotorods have the advantage of being economical and sensitive down to very low detection limits, but require the handling procedures and the use of solvents described earlier. The pumps are reliable and easy to use. We favour a flow of 3 l/min because of its low detection limit.

APPENDIX 1

Winds speed (m/s) and direction

observed every five minutes during air sampling

inside the treated areas

Wind speed (m/s) and direction
Blocks treated with aminocarb

Period No.	1A-302	2A-302	1A-206	1A-207	1A-209
1	0,6 O	0,8 SE	0,5 S	0,2 N	0,6 NE
2	0,6 O	0,7 SE	0,3 S	0,5 N	0,7 NE
3	0,4 O	0,8 SE	0,3 S	0,2 N	0,7 N
4	0,5 O	0,7 SE	0,9 S	0,4 N	0,6 N
5	0,6 O	0,9 SE	0,7 S	0,3 N	0,4 N
6	0,7 O	1,0 SE	0,7 N	0,2 N	0,4 NE
7	0,6 O	0,6 SE	0,4 N	0,2 N	0,6 N
8	0,5 O	0,9 SE	0,5 N	0,2 N	0,6 NE
9	0,7 O	1,8 SE	0,7 N	0,2 N	0,8 N
10	0,7 O	2,0 SE	0,4 N	0,2 N	0,5 NO
11	1,3 O	1,3 SE	0,2 N	0,2 N	0,5 NO
12	0,7 O	1,3 SE	1,4 N	0,2 N	0,5 NO
13	1,3 O	1,5 SE	0,9 N	0,2 N	0,5 O
14	1,1 O	1,8 SE	0,7 N	0,4 N	0,8 O
15	1,5 O	1,8 SE	0,2 N	0,4 SO	0,6 O
16	1,3 O	1,9 SE	0,2 N	0,2 S	0,5 O
17	1,4 NO	1,6 SE	0,5 S	0,4 S	0,7 O
18	1,6 O	1,1 SE	0,2 S	0,5 S	0,5 O
19	0,7 O	0,6 SE	0,2 S	0,5 S	0,5 NE
20	0,7 O	0,6 SE	0,6 S	0,5 SO	0,7 NE
21	1,8 O	0,9 SE	0,6 S	0,4 SE	0,8 NE
22	1,8 O	1,1 SE	1,8 S	0,5 SE	0,7 O
23	1,8 O	0,9 SE	1,3 S	0,7 S	0,4 O
24	2,0 O	1,4 SE	1,2 S	0,5 S	0,5 O

Wind speed (m/s) and direction
Blocks treated with aminocarb
(continued)

Period No.	2A-209	3A-209	4A-209	5A-209	1A-313
1	0,3 NO	0,5 O	0,9 SO	0,5 NO	0,4 O
2	0,5 SO	0,4 O	1,3 SO	0,5 N	0,2 O
3	0,7 SO	0,2 O	1,2 SO	0,5 N	0,7 S
4	0,4 SO	0,5 O	1,0 SO	0,4 N	0,5 SE
5	0,6 SO	0,2 NE	1,3 SO	0,5 N	0,4 E
6	0,5 SO	0,4 NE	1,3 SO	0,5 NO	0,5 E
7	0,5 SO	0,7 NE	1,1 SO	0,6 NO	0,5 E
8	0,9 SO	0,5 NE	1,3 SO	0,8 NO	0,5 SE
9	0,7 SO	0,2 N	1,4 SO	0,8 NO	0,5 SE
10	0,4 SO	0,2 O	1,3 SO	0,5 O	0,4 SE
11	0,2 O	0,2 SO	1,3 SO	0,7 O	0,4 SE
12	0,2 O	0,2 S	1,4 SO	0,5 O	0,4 E
13	0,5 O	0,5 E	1,5 SO	0,7 O	0,2 E
14	0,2 O	0,7 NE	1,3 SO	0,7 O	0,2 E
15	0,2 O	0,6 N	1,3 SO	0,4 O	0,4 E
16	0,4 O	0,7 N	1,4 SO	0,6 O	0,5 E
17	0,5 O	0,5 N	1,8 SO	1,2 O	0,4 E
18	0,5 O	0,5 N	1,7 SO	0,7 O	0,2 E
19	0,5 O	0,6 N	1,3 SO	0,7 O	0,7 SE
20	0,4 O	0,5 N	1,0 SO	1,1 O	0,9 SE
21	0,2 O	0,7 N	0,4 SO	1,1 O	0,7 SE
22	0,4 O	1,2 N	0,2 SO	0,5 O	0,3 E
23	0,5 O	1,4 N	0,8 SO	0,4 O	0,5 SE
24	0,3 O	0,9 N	0,8 SO	0,5 O	0,4 SE

Wind speed (m/s) and direction
Blocks treated with fenitrothion

Period No.	1A-106 (84-06-10)	2A-106 (84-06-12)
1	0,2 NE	0,2 N
2	0,2 NE	0,4 N
3	0,3 NE	0,2 N
4	0,2 NE	0,3 N
5	0,7 NE	0,3 N
6	0,3 SE	0,3 N
7	0,7 SE	0,2 N
8	0,3 SE	0,2 N
9	0,4 SE	0,2 N
10	0,9 SE	0,2 N
11	0,4 SE	1,3 O
12	0,2 SE	0,6 O
13	0,5 NE	0,4 O
14	0,2 NE	0,2 O
15	0,2 NE	0,5 S
16	0,2 NO	0,2 O
17	1,0 N	0,2 S
18	0,5 N	1,0 S
19	0,2 N	1,3 S
20	0,2 O	1,0 S
21	0,2 O	0,7 S
22	0,2 O	0,9 S
23	0,5 O	0,5 S
24	0,3 S	0,5 S

APPENDIX 2

Properties of droplet spectra

at each of the air sampling sites

TABLE (real diameters)

		Aminocarb	Fenitrothion
Group 1:	Droplets between	0 and 24	0 and 20
Group 2:	Droplets between	24 and 29	20 and 26
Group 3:	Droplets between	29 and 34	26 and 31
Group 4:	Droplets between	34 and 39	31 and 37
Group 5:	Droplets between	39 and 49	37 and 48
Group 6:	Droplets between	49 and 59	48 and 59
Group 7:	Droplets between	59 and 79	59 and 81
Group 8:	Droplets between	79 and 99	81 and 103
Group 9:	Droplets between	99 and 120	103 and 124
Group 10:	Droplets between	120 and 211	124 and 234
Group 11:	Droplets between	211 and 283	234 and 344
Group 12:	Droplets between	283 and 356	344 and 454

	INSIDE AREAS TREATED WITH AMINOCARB													
SITE NO.	DIAMETER GROUPS OF DROPLETS IN PERCENTAGE												TOTAL NUMBER /cm^2	DMN μ
	1	2	3	4	5	6	7	8	9	10	11	12		
1A 302	27.3	4.5	13.6	9.1	22.7	9.1	13.6	—	—	—	—	—	22.0	40
2A 302	28.6	10.0	10.0	17.1	18.6	14.3	1.4	—	—	—	—	—	5.8	31
1A 206	—	—	—	2.0	2.0	23.0	57.4	15.6	—	—	—	—	12.3	56
1A 207	—	0.2	0.5	2.6	9.0	31.7	37.3	12.2	3.0	3.6	—	—	50.8	55
1A 209	—	—	3.0	3.0	3.0	13.4	33.0	15.6	9.1	19.9	0.5	—	15.5	65
2A 209	1.1	1.1	1.1	2.2	12.9	29.0	40.9	11.8	—	—	—	—	7.8	53
3A 209	2.2	6.5	10.9	18.5	28.3	15.2	15.2	3.3	—	—	—	—	7.7	38
4A 209	19.9	12.2	5.5	6.1	17.7	12.7	22.1	3.9	—	—	—	—	15.1	38
5A 209	—	25.0	25.0	25.0	25.0	—	—	—	—	—	—	—	4	31
1A 313	14.3	—	14.3	42.9	14.3	14.3	—	—	—	—	—	—	0.6	32
	INSIDE AREAS TREATED WITH FENITROTHION													
SITE NO.	DIAMETER GROUPS OF DROPLETS IN PERCENTAGE												TOTAL NUMBER / cm^2	DMN μ
	1	2	3	4	5	6	7	8	9	10	11	12		
1A 106	Absence of detectable droplets													
2A 106	1.5	2.5	11.8	14.7	14.7	28.9	21.6	2.9	0.5	1.0	—	—	17.0	45

OUTSIDE AREAS TREATED WITH AMINOCARB														
SITE NO.	DIAMETER GROUPS OF DROPLETS IN PERCENTAGE												TOTAL NUMBER /cm²	DMN μ
	1	2	3	4	5	6	7	8	9	10	11	12		
1A 302	—	—	—	25.0	75.0	—	—	—	—	—	—	—	0.3	NOT CALCULATED
2A 302	17.0	—	17.0	33.0	33.0	—	—	—	—	—	—	—	0.5	
1A 206	25.9	39.5	25.9	8.6	—	—	—	—	—	—	—	—	4.8	
1A 207	Absence of detectable droplets													
1A 209	3.6	3.6	7.1	7.1	17.9	50	10.7	—	—	—	—	—	2.3	
2A 209	12.5	25.0	6.3	29.2	22.9	4.2	—	—	—	—	—	—	4.0	
3A 209	—	—	—	—	—	—	—	—	—	100.0	—	—	0.2	
4A 209	—	100.0	—	—	—	—	—	—	—	—	—	—	0.2	
5A 209	Absence of detectable droplets													
1A 310														
1A 313	—	37.5	—	25.0	25.0	12.5	—	—	—	—	—	—	0.7	

OUTSIDE AREAS TREATED WITH FENITROTHION														
SITE NO.	DIAMETER GROUPS OF DROPLETS IN PERCENTAGE												TOTAL	BMN μ
	1	2	3	4	5	6	7	8	9	10	11	12		
1A 106	Absence of detectable droplets													NOT CALCULATED
2A 106	—	—	—	20.0	—	60.0	20.0	—	—	—	—	—	0.4	

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